Fine structures of triexcitons in single GaAlAs/AlAs quantum dots

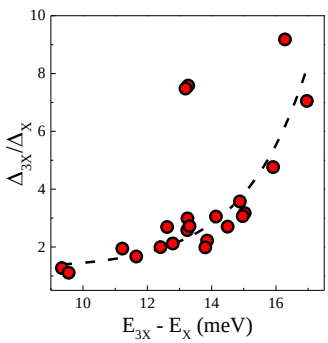
M. Molas,[1,2*] A. A. L. Nicolet,[2] A. Babiński,[1] and M. Potemski[2]

[1] *Faculty of Physics, University of Warsaw, Hoża 69, PL 00-681 Warsaw, Poland*
[2] *Laboratoire National des Champs Magnétiques Intenses, CNRS-UJF-UPS-INSA, 25, avenue des Martyrs, 38042 Grenoble, France*

The electron-hole exchange interaction and anisotropy of the confinement potential of quantum dots (QDs) induce the fine structure splitting (FSS) of exciton (X) emission lines into two components which are usually linearly polarised in two perpendicular directions. The FSS of neutral excitons has been largely studied in the past providing valuable information on the electron-hole exchange interaction between carriers which occupy the ground-state conduction and valence band levels (*s*-shells). The FSS of the triexciton state (3X) which consists of two excitons in a singlet configuration on the *s*-shell and one exciton on the excited level (*p*-shell) was much less investigated, so far.

We report on polarization-sensitive studies of multiexcitonic emission from single GaAlAs/AlAs QDs. To test the attribution of the observed excitonic lines to a particular multiexcitonic configuration, the polarization-resolved single-photon correlation experiments were performed. Notably, the cascade recombination of a quadexciton (two electron-hole pairs in the singlet configuration on the *s*-shell, and two pairs in the singlet configuration on the *p*-shell) to the single exciton was observed [1]. With these experiments, the recombination lines due to neutral single- (X) and bi- (2X) exciton (energy range of the *s*-shell emission) and the emission due to tri- (3X) and quad- (4X) excitons (energy range of *p*-shell emission) have been identified.

The electron-hole exchange interaction of the unpaired exciton in the 3X state leads to the energy splitting (Δ_{3X}) similar to the splitting (Δ_X) of the neutral exciton. Investigating the polarization-resolved micro-photoluminescence, we measured both Δ_X and Δ_{3X} in more than twenty QDs. The Δ_{3X} can be observed as the splitting of the 4X→3X and/or 3X→2X emission lines. The polarization axes of two linearly polarized components of both exciton and triexciton were also studied. It was found that the alignment of polarization axes of X and 3X-split components is identical, with one of the axes being along the [110] crystallographic direction [2].



The ratio Δ_{3X}/Δ_X as a function of the energy separation between the 3X (*p*-shell) and the X (*s*-shell) emission lines. Dashed line is a guide to the eye.

It was found that the Δ_{3X} always exceeds Δ_X. As shown in the figure, the Δ_{3X}/Δ_X ratio increases monotonically with the energy separation (E_{3X}-E_X) between the 3X (*p*-shell) and X (*s*-shell) emission lines. This relationship can be understood in terms of different spatial extent of the *s*- and *p*-shell orbitals. This difference appears to be more pronounced for dots of small size (larger $E_{3X} - E_X$).

We believe that studies of both Δ_X and Δ_{3X} energy splitting can provide new and more precise information on QDs, revealing more details on electron-hole exchange interaction and the actual form of the confinement potential.

[1] Y. Arashida, Y. Ogawa, and F. Minami, Phys. Rev. B 84, 125309 (2011).
[2] M. Molas, K. Gołasa, B. Piętka, M. Potemski, and A. Babiński, Acta Phys. Pol. A 122, 988 (2012).

* corresponding author: maciej.molas@fuw.edu.pl